US009901125B2

(12) **United States Patent**
Insley et al.

(10) **Patent No.: US 9,901,125 B2**
(45) **Date of Patent: Feb. 27, 2018**

(54) **DETERMINING CONDITIONS OF PERSONAL PROTECTION ARTICLES AGAINST AT LEAST ONE CRITERION**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1148 days.

(21) Appl. No.: **12/671,930**

(22) PCT Filed: **Aug. 25, 2008**

(86) PCT No.: **PCT/US2008/074205**
§ 371 (c)(1),
(2), (4) Date: **Feb. 3, 2010**

(87) PCT Pub. No.: **WO2009/051896**
PCT Pub. Date: **Apr. 23, 2009**

(65) **Prior Publication Data**

US 2011/0234374 A1 Sep. 29, 2011

Related U.S. Application Data

(60) Provisional application No. 61/124,830, filed on Aug. 31, 2007.

(51) **Int. Cl.**
A41D 13/00 (2006.01)

(52) **U.S. Cl.**
CPC ***A41D 13/00*** (2013.01)

(58) **Field of Classification Search**
CPC A62B 9/006; A62B 18/08; A62B 18/00; A62B 18/02; A62B 23/02; A62B 27/00;
(Continued)

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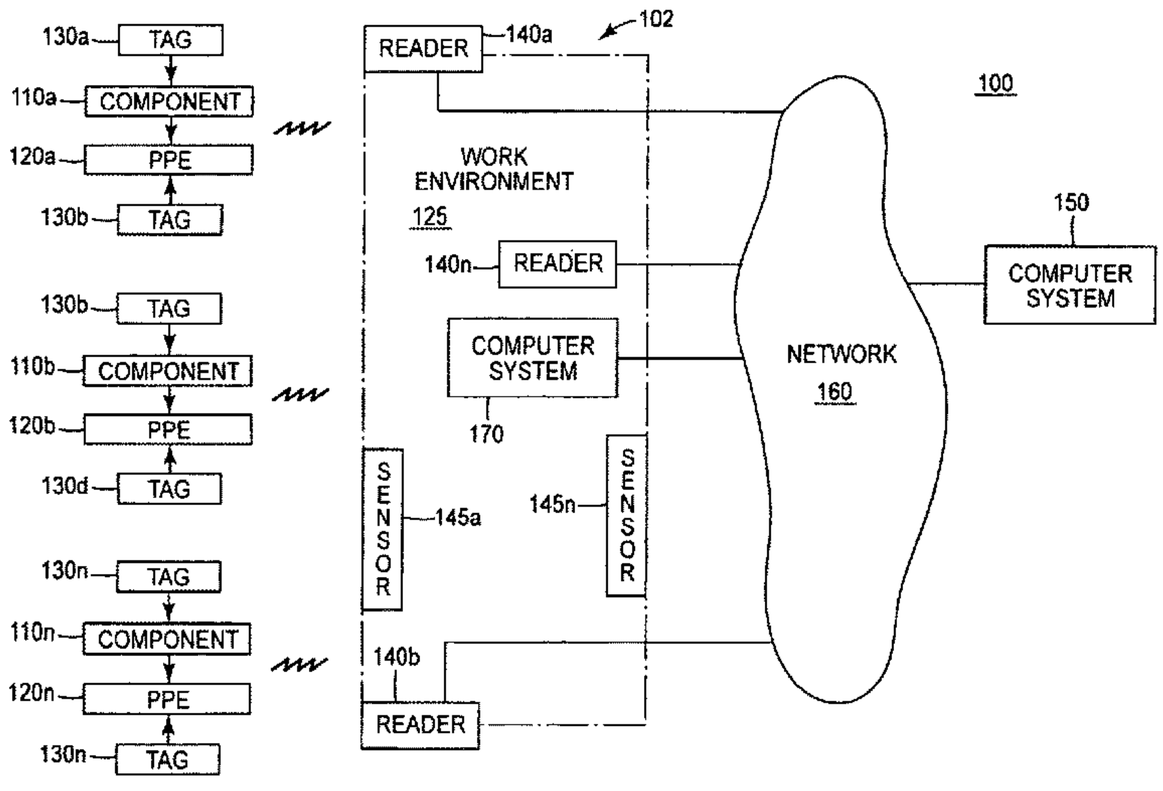
Primary Examiner — Nay Tun

(57) **ABSTRACT**

The present disclosure is particularly adapted for determining whether the condition of personal protection equipment PPE articles satisfies at least one criterion. A method and system provide at least one predetermined criterion that governs use of the PPE article in a working environment; a PPE article is configured with a smart tag, and a sensing device is provided that is configured to sense data in a working environment related to the predetermined criterion. Acquired data from the sensing device and the smart tag are processed in a data processing system to determine whether the condition of the PPE article satisfies the at least one predetermined criterion.

17 Claims, 5 Drawing Sheets



(58) **Field of Classification Search**
CPC G08B 21/02; A61B 5/0836; A61B 5/097; A61B 5/087; A61B 5/6803; A61M 16/06; A41D 13/00
USPC 340/521, 523, 584, 586, 572.1, 573.4, 340/10.1; 128/204.22, 204.23, 202.19, 128/206.24, 206.26, 903, 201.27
See application file for complete search history.

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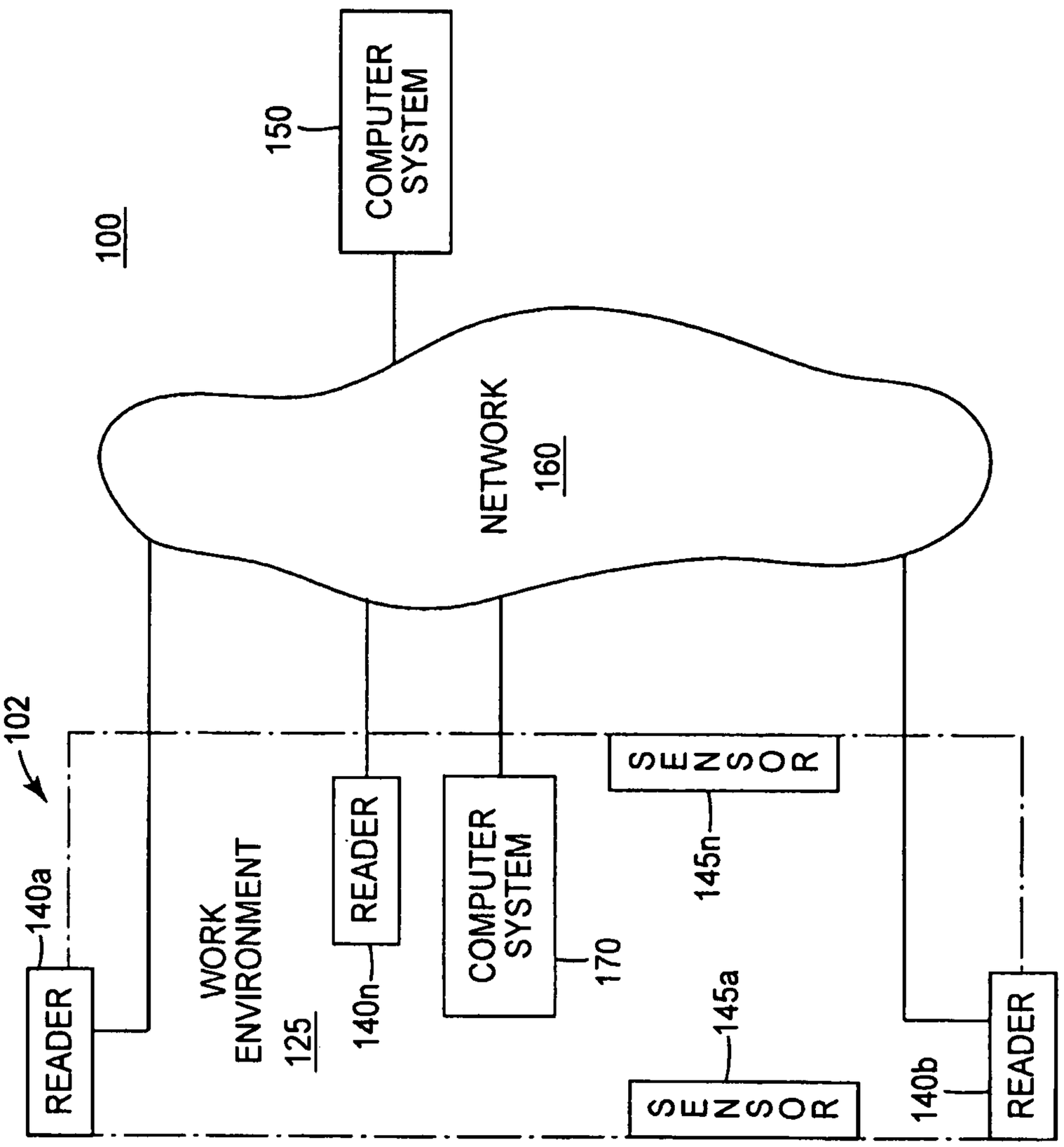
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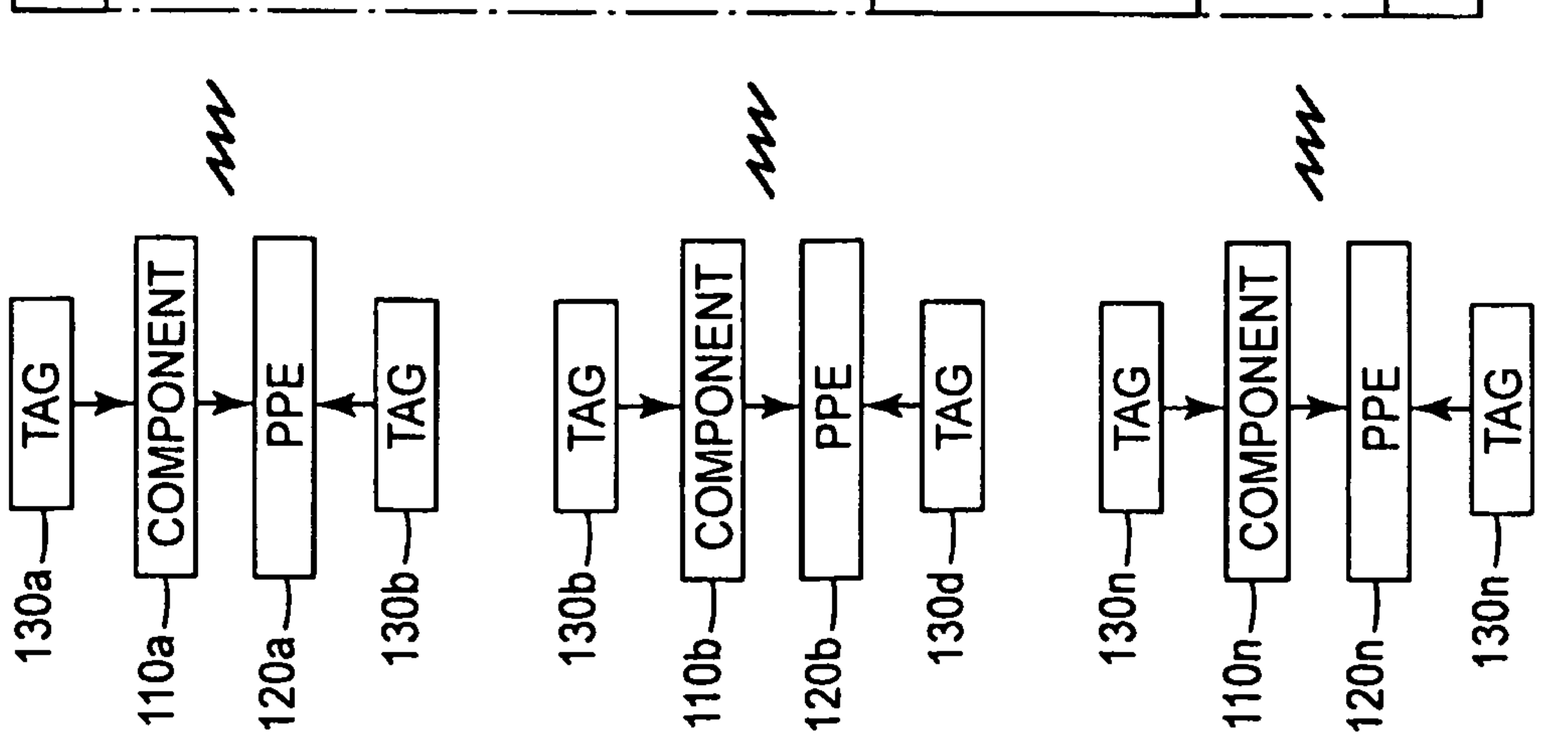
NETWORK
160
102
140a
READER
WORK ENVIRONMENT
125
140n
READER
COMPUTER SYSTEM
170
145n
SENSOR
145a
SENSOR
140b
READER

FIG. 1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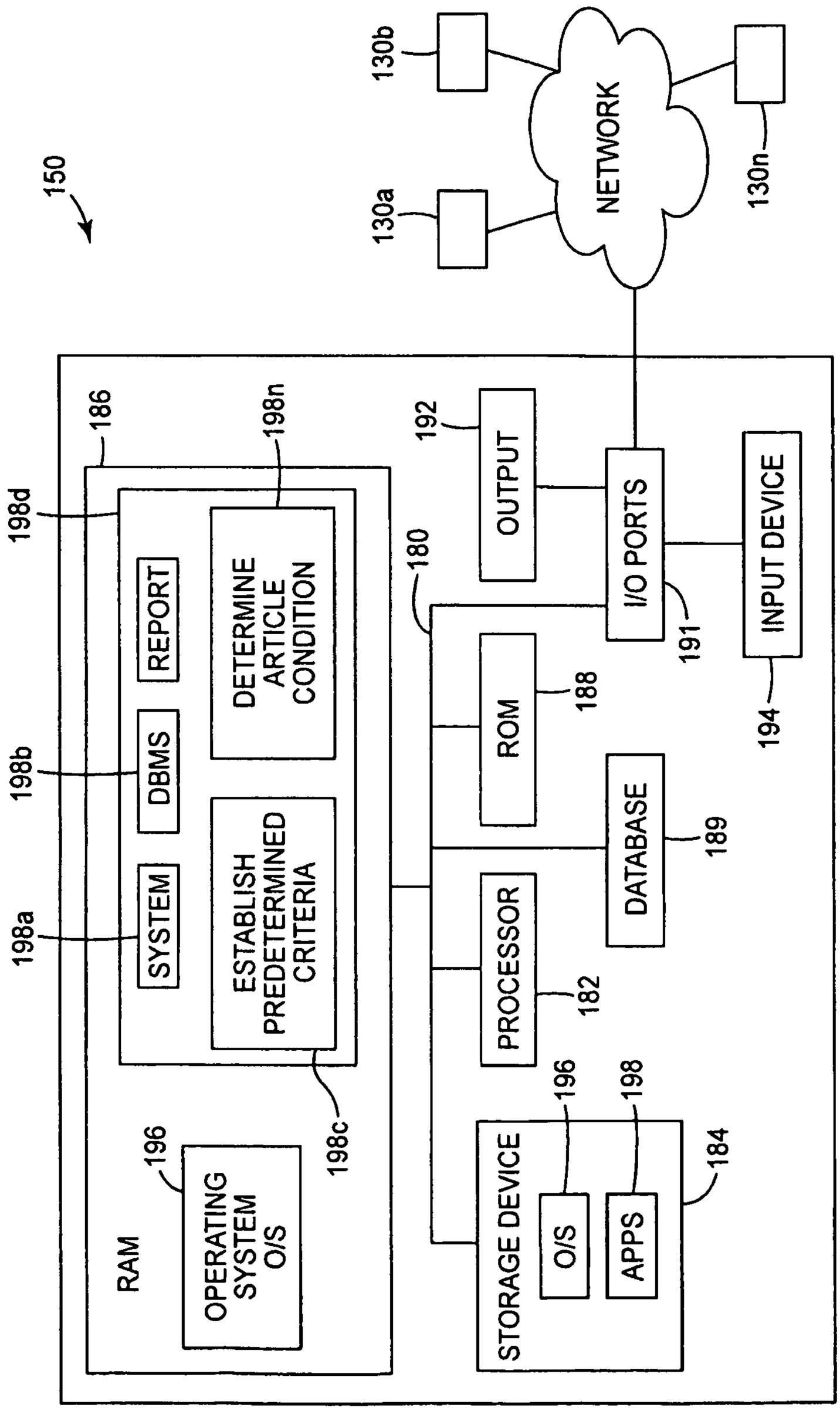
TAG
110a
COMPONENT
120a
PPE
130b
TAG
130b
TAG
110b
COMPONENT
120b
PPE
130d
TAG
130n
TAG
110n
COMPONENT
120n
PPE
130n
TAG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130b
130a
NETWORK
130n
186
198d
198b
198a
198n
SYSTEM
DBMS
REPORT
ESTABLISH PREDETERMINED CRITERIA
DETERMINE ARTICLE CONDITION
198c
RAM
196
OPERATING SYSTEM O/S
180
192
OUTPUT
I/O PORTS
191
INPUT DEVICE
194
ROM
188
DATABASE
189
PROCESSOR
182
STORAGE DEVICE
184
196
O/S
198
APPS

FIG. 2

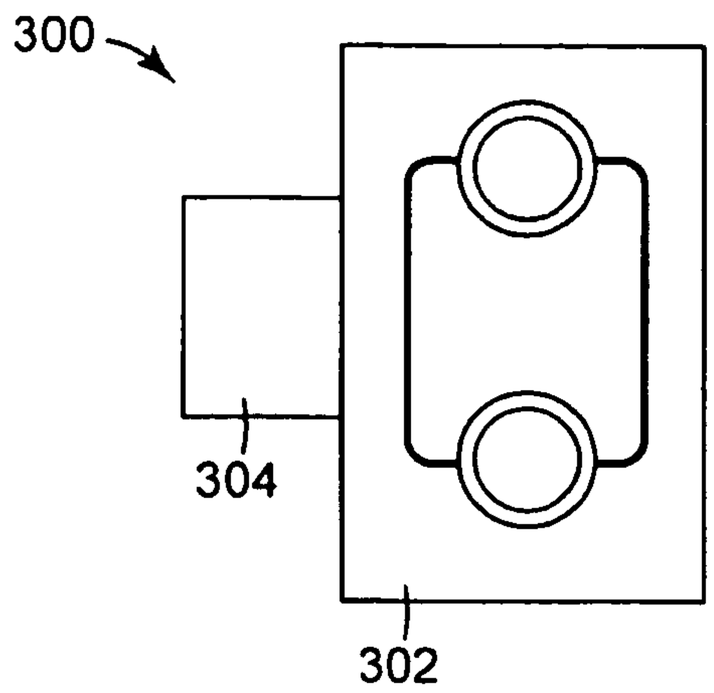

FIG. 3

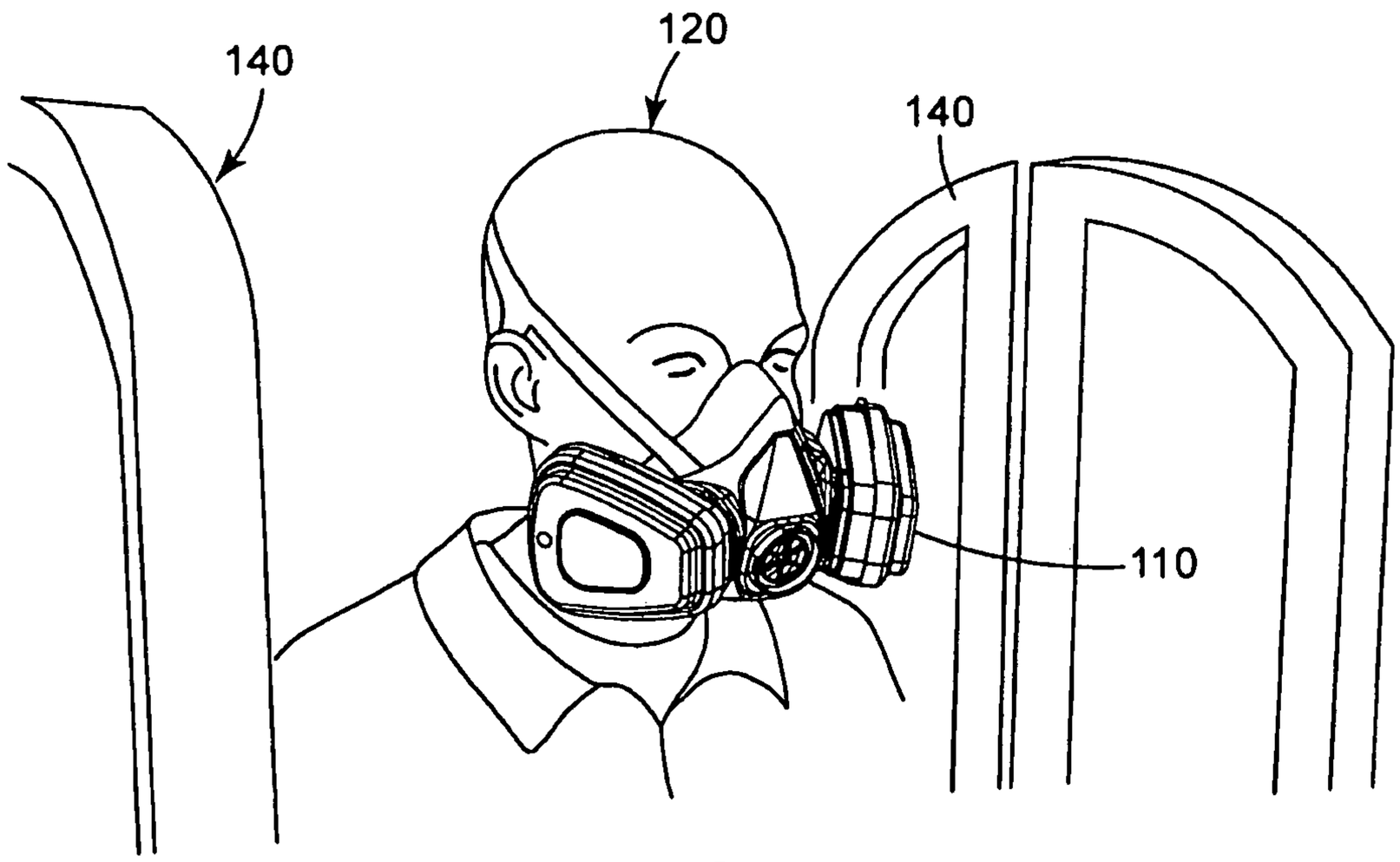

FIG. 4

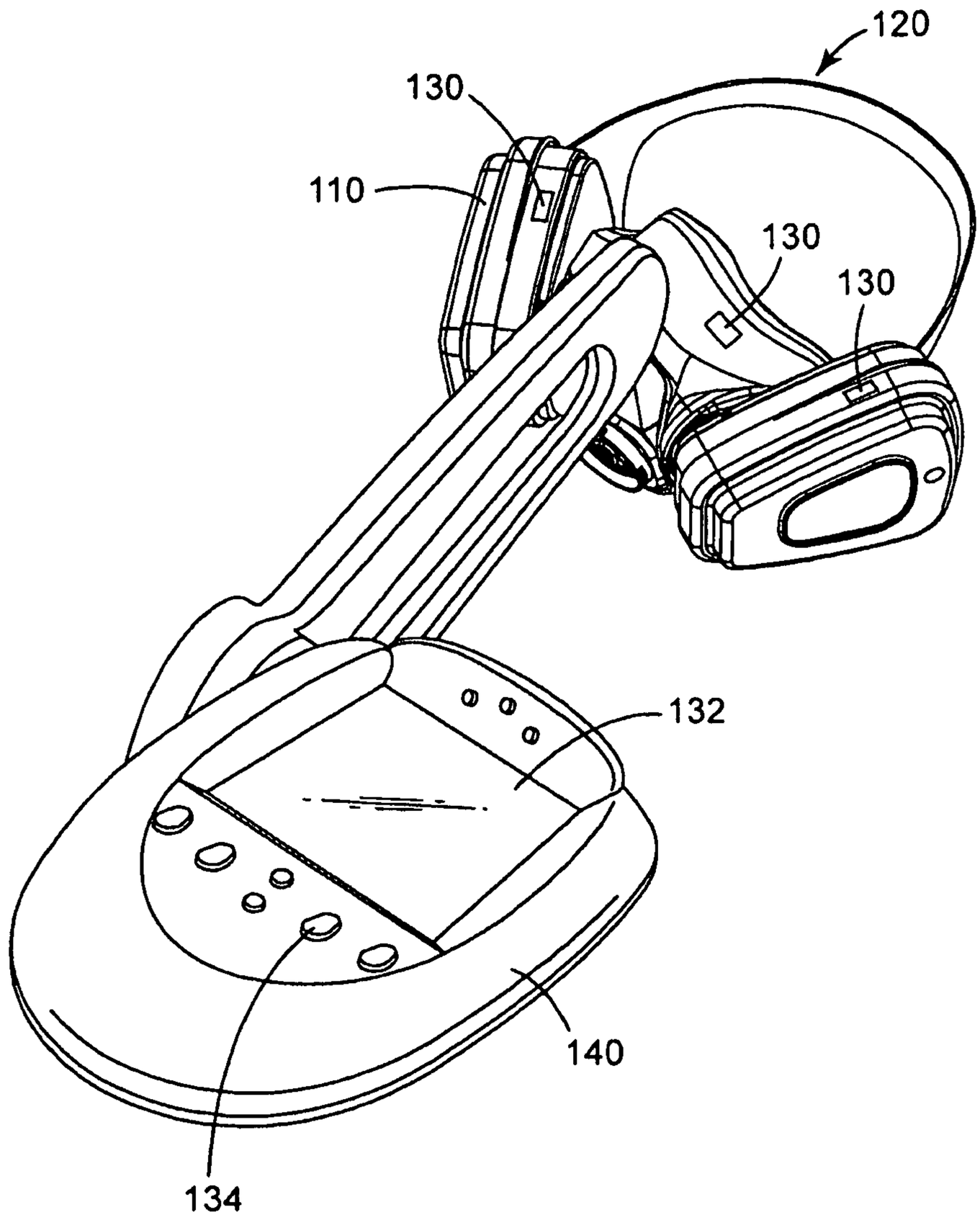

FIG. 5

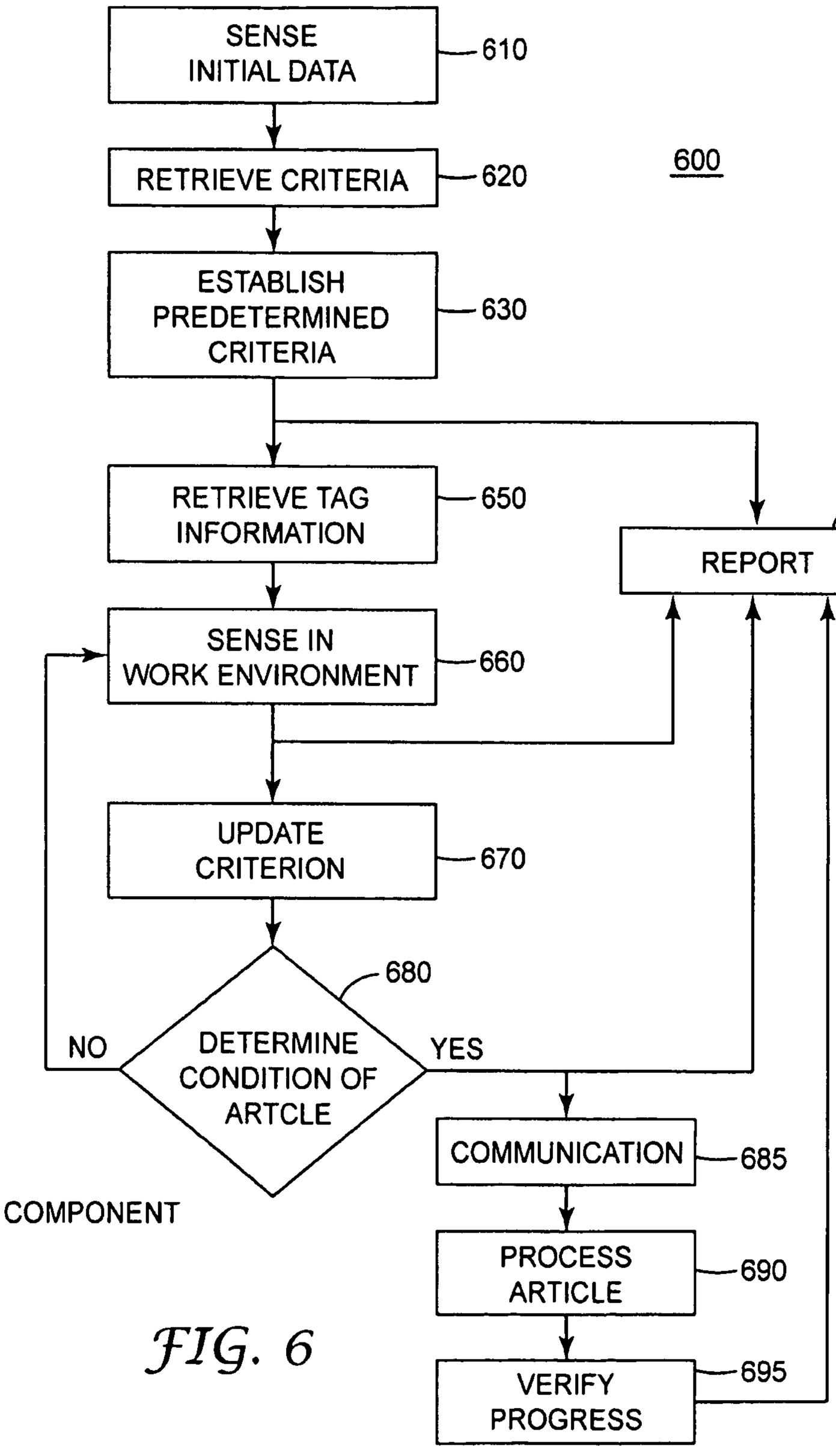
SENSE INITIAL DATA
610
RETRIEVE CRITERIA
620
600
ESTABLISH PREDETERMINED CRITERIA
630
RETRIEVE TAG INFORMATION
650
640
REPORT
SENSE IN WORK ENVIRONMENT
660
UPDATE CRITERION
670
680
NO
DETERMINE CONDITION OF ARTCLE
YES
COMPONENT
COMMUNICATION
685
PROCESS ARTICLE
690
VERIFY PROGRESS
695

FIG. 6

DETERMINING CONDITIONS OF PERSONAL PROTECTION ARTICLES AGAINST AT LEAST ONE CRITERION

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a national stage filing under 35 U.S.C. § 371 of PCT/US2008/074205, filed Aug. 25, 2008, which claims priority to U.S. Application No. 61/124,830, filed Aug. 31, 2007, the disclosure of which is incorporated by reference in its/their entirety herein.

BACKGROUND

Generally, this disclosure relates to determining a condition of personal protection (PP) articles. More particularly, it relates to methods and systems for determining a condition of a personal protection equipment (PPE) article, wherein the method and system determine whether the condition of the PPE article satisfies at least one criterion.

Maintaining the safety and health of workers is a major concern across many industries. Various rules and regulations have been developed to aid in addressing this concern, which provide sets of requirements to ensure proper administration of personnel health and safety procedures. To help in maintaining worker safety and health, some individuals may be required to don, wear, carry, or otherwise use a PPE article, if the individuals enter or remain in work environments that have hazardous or potentially hazardous conditions. Known types of PPE articles include, without limitation, respiratory protection equipment (RPE), e.g., for normal condition use or emergency response, protective eyewear, such as visors, goggles, filters or shields, protective headwcar, such as hard hats, hoods or helmets, hearing protection, protective shoes, protective gloves, other protective clothing, such as coveralls and aprons, protective articles, such as sensors, safety tools, detectors, global positioning devices, mining cap lamps and any other suitable gear.

For example, personnel in the nuclear industry may be required to wear radiation protective clothing and personal dosimeter devices. Law enforcement personnel are sometimes required to wear protective vests and helmets. There are numerous situations in the medical field in which healthcare workers must wear protective gowns, masks, face shields, gloves, etc. Workers in the food service industry are often required to wear hair netting, gloves, masks, etc. For example, there are also many industrial manufacturing scenarios in which personnel are required to wear protective or other specially designed articles in order to ensure a "clean" environment. For example, personnel in the micro-electronics manufacturing industry, biotech industry, laboratory/testing industry, are required to wear PPE articles not only to ensure their own safety, but to protect the equipment and devices which they assemble or perform various procedures with. There are also many industrial manufacturing scenarios in which personnel working in mines, oil refineries, metal grinding facilities, smelting facilities, industrial painting operations or pharmaceutical factories may be required to wear respiratory protection equipment (RPE).

There are many different kinds of RPE's utilized to prevent or reduce inhalations of contaminants, such as hazardous or toxic materials. The RPE's remove specific air contaminants by passing air through their air-purifying element. Proper use of such RPE's is contingent upon their condition and use being in accordance with appropriate sets

of rules, guidelines, regulations, certifications, or the like that govern use in a working environment. The rules, guidelines, regulations, certifications may be numerous and may be promulgated from many sources, including business and/or governmental sources. Many traditional RPE's typically do not, for example, include: any mechanism indicating when their ability to remove air contaminants has been reduced, if the workplace in which they are to be used contains contaminants they cannot handle; or if actual use of an RPE is outside recommended or required exposure times in a workplace. As such, determining if RPE'S are properly functioning and/or if their performances are in accordance with recommended or required rules can be quite demanding and at times quite onerous.

Moreover, facilities in which workers use PPE articles are often required to keep detailed records regarding the articles and the processing of them. For example, records may be kept regarding their use, conditions in which they were used, individuals who used them. In addition, records are kept as to when and whether PPE articles are to be serviced, changed-out, subject to maintenance, decontaminated or otherwise processed. As such, significant efforts and extensive recordkeeping must be undertaken. Clearly, making and keeping extensive records that contain all of the above-referenced information present a substantial administrative task. With more than 500,000 air contaminants that may be present in certain work environments, there are numerous rules and regulations to follow and gather information about. Accordingly, companies using such PPE articles have the responsibility to record their compliance with the appropriate rules and regulations. If not, potentially serious and/or costly consequences may rise.

Moreover, despite the extensive records that are required to be collected, adherence to various predetermined criteria is typically the responsibility of the user. Thus, compliance with a particular criterion regarding the condition of a PPE article may become an issue in work environments involving relatively large numbers of workers and/or respirators because of the relative difficulty in tracking worker habits and diligence, in part, due to the wearer not having means of assessing the level of hazards in his/her environment. Clearly, when predetermined criteria are not adhered to, workers are at a higher risk of exposure upon breakthrough of hazardous materials.

Furthermore, the predetermined criteria regarding proper and safe use of PPE articles are often predicated upon assumed work environment conditions prevailing during actual use, such as the kinds and concentrations of particulate in the workplace. Such assumptions also apply to other factors, such as the absence of other contaminants that might adversely affect proper RPE use. Also, such sets of criteria are predicated upon assumptions that the RPE articles will perform as intended. However, potentially serious and/or costly consequences may rise if the noted assumptions change which lead to violations of such rules and regulations. Moreover, it would be of substantial value to determine at which location(s) the assumptions have changed, thereby allowing corrections to be made to the environment or the articles.

Thus, needs exist for electronic methods and systems that overcome or eliminate the drawbacks and shortcomings of known approaches for determining the conditions of PPE articles against at least one criterion governing their use. Accordingly, there is need for electronic methods and systems that enable the conditions of PPE articles, such as RPE articles, to be determined against at least one criterion that

governs their use, let alone in a manner that is highly reliable, efficient, and economical.

SUMMARY

In one exemplary embodiment, the present disclosure provides a method for determining a condition of at least one protection equipment PPE Article against at least one criterion. Included in the method are: providing at least one PPE article configured with a smart tag; providing at least one predetermined criterion that governs use of the at least one PPE article in a working environment; providing at least one sensing device configured to sense data that is related to the at least one predetermined criterion; acquiring sensed data from the at least one sensing device; retrieving smart tag data from the smart tag; and, processing the sensed data and the smart tag data to determine whether the condition of the at least one PPE article satisfies the predetermined criterion.

In another exemplary embodiment, the present disclosure is directed to a system that comprises: at least one personal protection equipment article configured with a smart tag; at least one predetermined criterion that governs use of at least one personal protection equipment article in a working environment; at least one sensing device configured to sense data that is related to the at least one predetermined criterion; one or more data acquiring devices to acquire sensed data from at least one sensing device and smart tag data from the smart tag; and, a data processor for processing the acquired sensed data and the smart tag data to determine whether the condition of the at least one PPE article satisfies the predetermined criterion.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an exemplary PPE article condition determining system capable of implementing the process of the present disclosure.

FIG. **2** is block diagram of a computer system utilizable in an information retrieval system of the present disclosure.

FIG. **3** is a schematic view of a smart tag coupled to a sensor.

FIG. **4** is a schematic view of a wearer passing an exemplary data acquisition portal which may be used in some exemplary embodiments utilized in the system of FIG. **1** and wearing a smart tagged RPE article.

FIG. **5** is a schematic view of a smart tagged RPE including a portable reader.

FIG. **6** is a flow diagram of one exemplary embodiment of a process that may be performed according to the present disclosure.

DETAILED DESCRIPTION

The present disclosure substantially reduces drawbacks and shortcomings of known approaches for determining the conditions of personal protection equipment PPE articles. The foregoing is achieved through a method and system for determining a condition of at least one PPE article against at least one criterion. The method and system provide at least one predetermined criterion that governs use of the PPE article in a working environment. The method and system also provide that the PPE article is configured with a smart tag, and a sensing device that is configured to sense data in a working environment related to the predetermined criterion is also provided. Acquired data from the sensing device and the smart tag are processed to determine whether the condition of the PPE article satisfies the predetermined criterion.

FIG. **1** illustrates a block diagram of a personal protection equipment (PPE) article condition determining system **100**, according to one exemplary embodiment of the present disclosure. The PPE article condition determining system **100** includes an information retrieval system **102** networked to a computer system **150**. The PPE article condition determining system **100** is utilized for implementing a process for determining a condition of one or more articles of personal protection equipment (PPE) **120** *a-n* (collectively, **120**). The personal protection equipment articles may be coupled to a component **110***a-n* (collectively, **110**) for use in combination with the personal protection equipment articles. The PPE articles **120** are to be used in one or more working environments **125** (only one is illustrated). Exemplary working environments include, without limitation, paint shops, petrochemical refineries, mines, smelting facilities, pharmaceutical factories, or the like. "Predetermined criterion or criteria" as the terms are utilized in the present application refers to a set of rules, guidelines, regulations, recommendations, certifications, or the like that governs use of the at least one PPE article in a working environment.

The rules, guidelines, regulations, recommendations, certifications, and the like may be promulgated from any source, including business and/or governmental sources. Examples of the foregoing include, without limitation, the OSHA respirator regulation that requires respirators be National Institute for Occupational Safety and Health (NIOSH) approved, and must be used in compliance with the conditions of (NIOSH) certification. If other than approved types of respirators are used, that would be in violation of appropriate rules and regulations.

For example, government regulations, such as from OSHA, provide for nine classes of filters (i.e., three levels of filter efficiency each with three categories of resistance to filter efficiency degradation). Filter efficiency is the stated percentage of particles removed from the air. Filter efficiency degradation is defined as a lowering of filter efficiency degradation or a reduction in the ability of the filter to remove particles as a result of workplace exposure. Three levels of filter efficiency are 95%, 99%, and 99.97%. The three categories of resistance to filter efficiency degradation are labeled N, R, and P. The class of filter will be clearly marked on the filter, filter package, or respirator box. For example, a filter marked N95 would mean an N-series filter that is at least 95% efficient. Chemical cartridges that include particulate filter elements will carry a similar marking that pertains only to the particulate filter element. New classes of non-powered particulate respirators require new decision logic for selection of the proper respirator. The selection process for using the new particulate classification is outlined as follows: (1) The selection of N-, R-, and P-series filters depends on the presence or absence of oil particles, as follows: If no oil particles are present in the work environment, use a filter of any series (i.e., N-, R-, or P-series). If oil particles (e.g., lubricants, cutting fluids, glycerin, etc.) are present, use an R- or P-series filter. Note that N-series filters cannot be used if oil particles are present. If oil particles are present and the filter is to be used for more than one work shift, use only a P-series filter (e.g. guide: N for Not resistant to oil, R for Resistant to oil; P for oil Proof); and (2) selection of filter efficiency (i.e., 95%, 99%, or 99.97%) depends on how much filter leakage can be accepted. Higher filter efficiency means lower filter leakage.

Other respirator rules or regulations may define that certain classes of filtering-facepieces be used with particular contaminant and/or for certain exposure times based on contaminant concentration levels. So, if sensed workplace conditions regarding particulates indicate contaminant concentration values above or below acceptable limits, such could change the exposure time accordingly. For some products, such as electrical products in the workplace, OSHA requires third-party approval, such as Underwriter Laboratories. Still other OSHA PPE rules and regulations require hard hats, safety glasses, and safety footwear meet specific certification standards. Also, companies using PPE articles typically have the responsibility for ensuring compliance with the appropriate rules, regulations, recommendations, and certifications. Facilities are sometimes allowed to determine their own predetermined criteria based on the particulars of their work environment, PPE article, and the pertinent rules and regulations that govern the former. The present disclosure is not limited to OSHA rules and regulations, but any and all other appropriate rules, regulations, recommendations and guidelines.

In an illustrated exemplary embodiment, the PPE article **120** is an article of respiratory protective equipment (RPE) **120**. The RPE article **120** may be coupled to a component **110** used in conjunction with the PPE article. For example, the RPE article **120** may be a 7502 half facepiece respirator that is commercially available from 3M Company of St. Paul, Minn. The component **110** may be a 6001 Series organic vapor cartridge that is commercially available from 3M Company of St. Paul, Minn. The present disclosure is not limited by the foregoing combination of components and PPE articles, but envisions all suitable combinations. Other known types of PPE articles suitable for use in embodiments of the present disclosure include, without limitation, respiratory protection equipment (RPE) protective eyewear, such as visors, goggles, filters or shields, protective headwear, such as hard hats, hoods or helmets, hearing protection, protective shoes, protective gloves, other protective clothing, such as coveralls and aprons, protective articles, such as sensors, safety tools, detectors, global positioning devices, mining cap lamps and any other suitable gear.

In one exemplary embodiment, the information retrieval system **102** includes one or more smart tags **130***a-n* (collectively, **130**); one or more data acquiring devices **140***a-n* (collectively, **140**) that acquire data from the smart tags; and, one or more sensors **145***a-n* (collectively, **145**) that, as will be described, sense for variables that are related to usage of the PPE article being tracked. Given the number of different kinds of smart tags, data acquiring devices, and sensors that can be used, there exists a large number of combinations for the system **102** that can be constructed depending on the PPE articles and the appropriate predetermined criterion. Accordingly, the exemplary information retrieval system **102** is but one of many different and suitable types.

The present disclosure contemplates use of any suitable smart tag known in the art. In one exemplary embodiment, the smart tag **130** is directly attached to the PPE article **120**. Essentially, a smart tag is a data carrier that carries data accessible by suitable methods, including, but not limited to, electronic, optical, or other wireless technology. Data on a smart tag may, typically, at least, include tag identification information, such as an identification number (e.g., serial number). In addition, the smart tag **130** may contain other information relating to the article of PPE **120**, such as the type of article used; historical information relating to the article, information about the user (who used it, where it was used, under what condition it was used, etc.) maintenance or other type of processing, information about who wrote information onto the smart tag; any requirements relating to the article and its associated component, and/or their use, whether any such requirements have been satisfied, such as any certifications obtained, and any other useful information, such as change-out history, or the working environment. Also, information regarding the user of the article of PPE may be on the smart tag **130**; such as, medical information, information relating to fit-testing, training, job responsibilities, seniority or experience, access privileges or any other information.

Smart tags include passive and active types. Generally, passive tags do not include an internal power source and the data carried thereby may be encoded at manufacture. Data information may be acquired from a passive smart tag, for example, radio frequency, microwave, infrared, or other wireless modes; or by optical readers or other appropriate electronic or optical technology. One type of passive smart tag is radio frequency identification (RFID) tag, wherein a transponder carries read-only data. Another type of passive smart tags may be rewritable. RFID technology is known and understood by those skilled in the art and, hence, only a brief description is included herein for facilitating understanding of the present disclosure. Passive RFID type smart tags are typically provided in the form of small labels or the like that include a coiled, etched or stamped antenna, a capacitor, and a substrate on which the components are mounted or embedded. For some metallic smart tags, the metallic portion itself may serve as the antenna. The RFID type smart tag may be embedded in or attached to the PPE articles **120** by any suitable approach. For example, the smart tags may be joinable as by being adhered, fastened, sewn, friction fitted, mechanically clipped, welded (e.g., ultrasonically) or molded, etc. onto or into the components, included as an integral component of the article or securely attached by any suitable means.

Besides passive RFID smart tags, other passive smart tags may include, without limitation, optical kinds including barcode and optical character recognition systems; electromagnetic systems; and acoustomagnetic systems.

On the other hand, active smart tags tend to carry their own internal power source as well as data, and an appropriate antenna for allowing exchanging of their data. The internal power supply may include a micro-battery, a thin film battery, or the like. Active smart tags may be reprogrammable and include, besides an antenna, a microchip to receive and store additional information beyond the information contained in its fixed code. Active smart tags may exchange their data information with data acquiring and/or transmitting devices, such as including, without limitation, readers and/or writers, scanners, and/or data receivers, such as wireless receivers. The exchange may be initiated by the active smart tag itself once it finds a suitable or designated, reader, scanner, or receiver. The active smart tags may transmit their data in response to triggering or interrogating signals, they may actively transmit their data independent of such signals. For instance, the active smart tags may continuously or periodically transmit data to appropriate readers and/or writers, scanners, or receivers. As noted, some active smart tags include the capability to receive and store additional information beyond that contained by its encoded data. Other kinds of active smart tags may be configured to be rewritable. For instance, an active RFID smart tag may be rewritable, as by an RFID reader/writer.

Other kinds of active smart tags include a real time location system (RTLS) smart tag. An RTLS active smart tag is an active tag having a transmitter and a receiver and it

communicates with a network according to a particular protocol. RTLS systems can work to determine the position of the smart tag in a 2-dimensional or 3-dimensional space. For example, a RTLS smart tag generally uses one or both of the following wireless location-based methods for determining the position of a smart tag or the object the tag is attached to.

The first is a Time Difference of Arrival (TDOA) method. In one implementation of this method, the smart tag will broadcast a signal to multiple wireless receivers **140** at known locations. The time at which the signal is received by each receiver is measured, and a set of equations can be used to determine the position of the smart tag. Examples of systems using this method are a global positioning system (GPS) or a system using low frequency radio transmitters that use the time interval between radio signals (LORAN). Another example is an active smart tag used in a WiFi system that determines how long a signal takes to reach a receiver. Other companies that use this principle for RTLS systems are AeroScout Inc., Redwood City, Calif.; NanoTron Technologies, GmbH, Berlin, Germany; WhereNet, Santa Clara, Calif.; and, MultiSpectral Solutions, Inc., Germantown, Md.

A RTLS may also use a Received Signal Strength Indicator (RSSI) method. This latter method requires tags or fixed transceivers to measure the received power (signal strength) of the incoming signals. Then, using either known variations of signal strength vs. distance from transmitters, or by measuring the signal strengths at various locations and matching these measured strengths to the measured strengths, position can be determined. Companies that provide commercially available products using the RTLS system include Wavetrend, Fairfax Va., and PanGo Networks, Framingham, Mass.

One example of an active smart tag suitable for use in an RTLS system is an Ekahau™ smart tag, which communicates with wireless receivers in a wireless local area network (WLAN) through IEEE 802.11b and 802.11g standards. The Ekahau™ smart tag is commercially available from Ekahau, Inc., Reston Va. and may be used in the present exemplary embodiment. Other examples of suitable smart tags may be provided, and include those, such as described, in U.S. Pat. No. 6,853,303, which is incorporated herein.

As noted, the data from the smart tag may be acquired by data acquiring devices **140**, such as readers **140**, readers/writers **140**, scanners **140**, or receivers, such as wireless receivers **140**, as well as other suitable devices. A reader or scanner may include an antenna for transmitting a trigger signal to a smart tag and receiving a return signal from the tag containing information. The data acquiring devices **140** may be placed in any one or more of the critical spots of the process including but not limited to the area where the PPE articles **120** are handed out to the individual. In some exemplary embodiments, one or more data acquiring devices **140**, such as readers or scanners **140** are hand-held. For example, a receiver **140** may be a wireless node of a wireless local area network (WLAN) that may provide an internet access point.

The readers **140** may be linked to a remote programmable electronic system **150** through the network **160**. The programmable electronic system **150** includes functionalities that enable tracking usage of the PPE articles against at least a predetermined criterion. These may include, but are not limited, to certifications regarding servicing, repairing, cleaning, maintaining, decontaminating, or other processing the PPE articles. For example, if the cumulative exposure time of the RPE article, in the workplace exceeds a certification value(s); the concentration level(s) of particular contaminants exceed certification value(s); the presence of unexpected contaminants in the working environment; persons with particular profiles should not be exposed to various contaminants; particular kinds of PPE articles should or should not be used when certain contaminants are present.

As illustrated in FIG. **1**, the reader **140***a* may be stationed at the entrance of the work environment **125** and acquires relevant data of the wearer; component **110**, and the PPE article **120**, such as one or both of: at the start of the workday or shift and at the end of the work day or shift. The readers may be in a variety of one or more other locations, such as where the components are removably coupled to the PPE article. This information is sent to a database of the computer system **150** for the purposes which will be described. Alternatively or additionally, one or more readers **140** may be located within the actual work environment **125** so as to provide opportunities for wearers obtaining readings in the work environment **125**. Alternatively or additionally, a portable reader **140** may be utilized (see FIG. **5**), such as where the PPE articles **120** are issued prior to entering the work environment. A typical portable reader **140** may have a display **132** and keypad **134** for data input and are wirelessly connected to the network **160**. The portable reader **140** may be used when the tagged PPE articles are in the work environment **125** or at the end of a work shift. The present disclosure does not place limitations on the locations or timing of reading of the tagged PPE articles.

Exemplary suitable sensors **145** of some exemplary embodiment may include, without limitation, measurement of the following analytes/parameters: electromagnetic radiation (such as thermal and visible), ionizing radiation, nuclear radiation, chemicals (such as liquids, solids, vapors, gases and mists/aerosols), biological analytes, particulates, noise, heat stress, motion, as well as others. The transducers may be of the electrical or optoelectronic type. The sensors **145** may be mobile or stationary in the work environment and connected, as for example, by wireless to the network. In the mobile mode, the sensors **145** may be disposed on the PPE or on the component. The sensed information data is generally related to the usage of the PPE article being tracked as will be explained. The data, as noted, includes, without limitation, concentration levels, types of contaminants, presence or absence of contaminants, insufficient or no current to run a circuit of the PPE article, inadequate pressure for a self-contained breathing apparatus (SCBA), insufficient or no battery power, breakthrough of a chemical through a filter, or inoperable safety mechanisms. The present disclosure is not limited by these examples since what is sensed encompasses any known factors that may relate in any way to the condition or use of the PPE articles.

Reference is made to FIG. **3** for illustrating a combination sensing and smart device **300** that may be attached directly to an article of PPE (not shown). The sensing and smart device **300** includes a combination of photo-ionization detector (PID) sensing device **304**, and the Ekahau™ smart tag **302**. The functionalities of the sensing device and the smart tag remain the same despite being physically coupled together. The combination sensing device **300** may also provide location information that may be mapped to identify a location(s) in which the concentration levels may change (e.g., spike).

The network **160** may include, without limitation, a local-area network (LAN), wide area network (WAN), the internet, or a wireless network, such as a wireless local area network (WLAN). The programmable electronic system **150**

may represent any type of computer system, programmable logic devices, or the like. The computer system **150** may include server computers, client computers, PC-based servers, minicomputers, midrange computers, mainframe computers; or other suitable devices. In some exemplary embodiments, the computer system **150** may include portable computer systems including laptops, handheld computer systems. In addition, the system **100** may include one or more local computer systems **170** located in the work environment **125**. As such, workers may be able to obtain pertinent data, for example, a real-time assessment of the condition of the PPE article while in the work environment **125**. The local computer system **170** typically includes portable computer systems including laptops, handheld computer systems. The local computer system **170** may also include other computer systems, such as, client computers, PC-based servers, minicomputers, midrange computers, mainframe computers; or other suitable devices.

With continued reference to FIG. **2**, there is depicted a server computer system **150**. It is depicted as comprising at least one system interconnect bus **180** to which various components are coupled and communicate with each other. Coupled to the system interconnect bus **180** is at least a single processor unit **182**, storage device **184**, memory such as random access memory (RAM) **186**, read only memory (ROM) **188**, a relational database management system (DBMS) **189**, and input/output (I/O) ports **191**. The relational database is a computer database management system **189** controlling the storing, updating, and retrieving of data to database files for use in tracking usage of PPE articles against the one or more predetermined criteria under the control of the applications to be described hereinafter. The database files contain all relevant information pertaining to the operational parameters of the readers. Furthermore, one or more output devices **192** such as a display, as well as one or more user interface input devices **194**, such as a keyboard and/or pointing device is respectively coupled to the I/O ports **191**. In known fashion, the output and input devices **192** and **194**; respectively permit wearer interaction with the computer system **150**. The I/O port **191** typically includes various controllers (not shown) for each input device **194**, such as a keyboard, mouse, joystick, and the like, as well as the output device **192**, such as an Ethernet network adapter, infrared device and display (not shown). The processor **182** controls the input device **194** which provides a user interface for allowing a wearer to access information, such as usage history of PPE articles being tracked.

The processor unit **182** may be any suitable processor and sends and receives instructions and data to and from each of the computer system's components that are coupled to the system interconnect bus **180** to perform system operations based upon the requirements of the computer system's operating system (OS) **196**, and other specialized application programs **198***a*-**198***n* (collectively **198**).

The ROM **188** typically controls basic hardware operations. The storage device **184** may be a permanent storage medium, such as a hard disk, CD-ROM, tape, or the like, which stores the operating system **196** and the specialized applications programs **198**. The RAM **186** is volatile memory. The contents of the RAM **186** may be retrieved from the storage device **184** as required. Illustratively, the RAM **186** is shown with the operating system **196** and application programs **198** concurrently stored therein. The program code of the operating system **196** and/or application programs **198** is sent to the RAM **186** for temporary storage and subsequent execution by the processor **182**. Additionally, the RAM **186** is capable of storing files from the operating system **196**, as well as files from one or more application programs.

An information retrieval system application program(s) **198***a* is one typically utilized for controlling operations of the information retrieval system **102** including the functionalities described herein with respect to the smart tags **130**, data acquiring devices **140**, and sensors **145**. Provision is made for a suitable database management system application **198***b* to run the database **189** in a manner consistent with the present disclosure. Also, provision is made for an establish predetermined criteria application **198***c*. This may, in some cases, be a software application provided by a manufacturer of the PPE article that are to be tracked. In some exemplary embodiments, this software application may be used to establish conditions for proper usage of the PPE article as determined by the rules and regulations established by the government, insurance company or other entity interested in the results. The establish condition determining application **198***c* is updatable to establish a new or current criteria related to actual conditions of the PPE article in the working environment, as for example, by using the data acquired.

A report generating application **198***d* is provided that may generate reports containing a variety of data in different reporting formats tailored for purposes including those described below. These reports may be generated to allow workers, supervisors, health professionals to access the history and status of articles; their medical information, information relating to fit-testing, training, job responsibilities, seniority or experience, access privileges or any other information, history of PPE article servicing, maintenance, change-out, as well as other information.

The determining PPE condition application **198***n* of the present disclosure enables determining the conditions of the tagged PPE articles **120** following retrieval of smart tag information and sensed data information against at least one predetermined criterion established by the establish predetermined criteria application **198***c*.

Reference is made to FIG. **6** for illustrating one exemplary embodiment of a PPE article condition determining process **600** that may be implemented by the PPE article condition determining system **100**. The PPE article condition determining process **600** enables determining the condition of the PPE articles **120** tagged with a smart tag **130** after processing data received by the smart tag and/or one of the sensors. The term "condition" as utilized in the present application means the particular state of one or more factors that affect the operational life or usefulness of one or more PPE articles. In this exemplary embodiment, the condition being determined is if the RPE **120** should be serviced after exposure to contaminants for a certain exposure over time.

In a Sense Initial Condition block **610** of the PPE article condition determining process **600**, sensing is performed by one or more of the sensors **145**. In this embodiment, the type of PPE articles **120** being tracked determines which variables in the working environment should be sensed and, therefore, which sensors to be used. Since conditions of respirators are being determined in this exemplary embodiment, the sensor **145** is of the type that collects data bearing upon the PPE article's condition relative to its servicing. In particular, concentration levels of a particular hazardous material over a period of time may be sensed as by the PID sensor **145**. As will be explained, the concentration levels may assist in establishing a predetermined criterion regarding the servicing condition of the tagged PPE article. The initial sensed data from the sensor **145** that is collected may

reflect low, average, and peak concentration levels of the particular hazardous material(s). Other sensors may detect for the presence of other contaminants that, for example, may be incompatible with the respirator being used. While hazardous materials are being monitored in the exemplary embodiment, the present disclosure envisions that there are no limits on the variables that may be sensed and the relationship these variables have in determining the condition of the PPE article. For example, variable factors relating to other aspects of usage of the RPE article may include: charge of a battery, amps in a circuit, and circulating air pressure of their respirator. The condition determining process allows this data to be forwarded to the database.

The PPE article condition determining process **600** then proceeds to Retrieve Criteria block **620**, whereat the establish a predetermined criteria application **198***c* retrieves at least one appropriate predetermined criterion (or criteria) for the PPE article whose condition is being determined. If the PPE article being monitored is a respirator, the pertinent criterion that is relevant to its condition (e.g., servicing) may be selected. The set of criteria is stored in memory. The set of criteria may be obtained from many different sources that provide guidance on the proper servicing of the PPE article as noted above. The set of criteria may be downloaded, for example, from the internet. Typically, the manufacturer of the PPE article may provide the set of criteria that is relevant to the condition of the PPE article. The set of criteria may be developed by government, industry, the company operating the system **100**, an insurance company, standards' bodies, and persons of interest, such as a safety officer, industrial hygienist, or the like. In the present exemplary embodiment, the set of criteria may relate to minimum or maximum exposure times that a respirator may safely operate before being serviced. Another example of a set of criteria relates to proper battery charge of an PPE article relative to acceptable limits of performance of the PPE article. Still another example of a set of criteria that governs use of when a respirator should be serviced, repaired, or otherwise treated, is based on inadequate pressure existing, such as in a self-contained breathing apparatus (SCBA).

Following the Retrieve Criteria block **620**, the condition determining **600** proceeds to an Establish Predetermined Criteria block **630**. In the block **630**, the initial data that may be sensed in the block **610** is processed in the database by the establish predetermined criterion application **198***c*. As a result, there is established a predetermined criterion for the PPE article **120** in the actual working environment. In such an exemplary embodiment, the predetermined criteria application(s) **198***c* analyzes the collected monitored data in terms of the set of criteria retrieved in the block **620** to determine the predetermined criterion that will determine if the condition of the PPE article, during its actual use in the working environment, is satisfied. For example, based on the initial concentration levels in the work environment, a maximum exposure time for the respirator is then determined before it should be serviced. The predetermined criterion takes into account the exposure time recommended or required for the respirator in the work environment.

The condition determining process **600** may further include a Reporting block **640** that follows the Establish Predetermined Criteria block **630** under the control of the reporting application **198***b*. The Reporting block **640** is capable for generating a report relevant to a wide variety of subjects including, but not limited to, the condition of the PPE article, the worker, or even its associated one or more components, the initial sensed data, the work environment, and other pertinent information. Typically, the Reporting block **640** generates a report in a format acceptable by an entity requesting the report, for example, the business entity using the system **100**, or a governmental agency, such as OSHA. While the Report block **640** follows Establish Predetermined Criteria block **630**, reports may be generated at any one or more points in the process. The reports may be generated by the workers or other persons of interest or even in response to requests by the government. The reports generated may be transmitted across the interne as well. There is no time limit to generating the reports.

The PPE article condition determining process **600** proceeds to a Retrieve Tag Information block **650**. In this embodiment, the system **102** retrieves or acquires the data, as noted above, from the smart tags **130** by the data acquiring devices **140**, such as a receiver **140**, as well as the sensors **145**. The smart tag **130** of this embodiment may be an Ekahau™ type **130** to provide location information as well as the data of the smart tag. Other smart tags can be provided. The receiver **140** may be located in any number of places, such as the entrance to a work environment **125**. In particular, retrieving information from the smart tag **130** may provide data as to when and where the wearer enters the working environment, exits the working environment, or passes another location. Optionally, in order to identify the wearer, the latter may present his/her badge to an appropriate data acquiring device **140**. The smart tag **130** or the badge may also include other data regarding the wearer, such as medical, fit test, job description, seniority, training, and other qualifications. The retrieved data is forwarded to the database **189** of the computer system **150**, and, if operational, the local computer system **170**. The data may include the identification of an article, date, and/or timestamp, as well as the location of the data acquiring device. The present disclosure envisions that the retrieving tag information may occur more than once and at any suitable number of points in the determining process.

The PPE article condition determining process **600** then proceeds to the Sense In Work Environment block **660**. In the Sense In Work Environment block **660**, the sensor **145**, such as the PID sensor **145**, is operable for providing current sensed data regarding, for example, current concentration levels of benzene vapor in the work environment **125**. This data is forwarded to the database. The PPE article condition determining process **600** may proceed to the Update Criterion block **670**. In the Update Criterion block **670**, the data from the database from the sensor **145** is acted upon by the establish predetermined criteria application **198***c*, where a new analysis is conducted to determine whether an update predetermined criterion is to be used. Such updating enhances the overall advantages provided by the present disclosure. While the Sense In Work Environment block **660** and the Update Criterion block **670** are illustrated, they need not be present in the PPE article condition determining process **600**. In such a case, the process **600** may proceed to the Determine Condition of PPE Article block **680**.

In either event, the PPE article condition determining process **600** then may proceed to the Determine Condition of PPE Article block **680**. In the Determine Condition of PPE Article block **680**, the condition determining application **198***n* determines if the condition of the PPE article satisfies the initial or updated criterion. In particular, in an exemplary embodiment, the exemplary determination is made as to whether a respirator has an exposure time that exceeds the recommended exposure time of the article in the working environment as determined in the Establish Predetermined Criterion block **630**. If the actual exposure time does exceed the recommended exposure time then the respirator has

satisfied the predetermined criterion, that the article should be serviced. In the Determine Condition of PPE Article block **680**, the article has satisfied the predetermined criterion servicing (i.e., Yes) since its actual exposure time does exceed the recommended exposure time, when compared to the recommended exposure time, indicated in the Establish Predetermined Criteria block **630** or the Updated Criterion block **670**. Conversely, the servicing condition is not satisfied (i.e., No) if the actual exposure time does not exceed recommended exposure time as determined in the Establish Predetermined Criteria block **630** or the Updated Criterion block **670**.

The PPE article condition determining process **600** includes a Communicate block **685**, whereat compliance or non-compliance is communicated, using any known communication methodology, to appropriate persons, or reporting entities. Such a communication may be transmitted to the user, the database, the user's supervisor, industrial hygienist or other appropriate personnel. The process of this block may be occurring at other times. In one exemplary embodiment, such communications may be made as a message to display screen of the computer or to a personal digital assistant (PDA). It will be appreciated other suitable software applications may be used to provide such communication. In one exemplary embodiment, such determinations may be made as a message to display screen of the computer or to a personal digital assistant (PDA). It will be appreciated other suitable software applications may be used to provide such communication. In some exemplary embodiments, such communications may include an alarm or audible signal to appropriate persons including the user and/or supervisor.

The PPE article condition determining process **600** also includes a Process Article block **690** that may follow the Communicate block **685**. A wide variety of processes may be performed to handle the article, such as cleaning, refurbishing, disposal or the like. A wide variety of disposal methods are contemplated, for example, being displaced in a bin, this will ensure that the PPE article will not be used until some other steps are undertaken.

The PPE Article Condition Determining process **600** may then proceed to Verify Processing block **695**. In the Verify Processing block **695**, a data acquiring device **140** may be stationed adjacent to the processing area, such as a disposal bin, for acquiring relevant identification data from its smart tag **136** that the PPE article **120** has been processed. The verification data is transferred to the server's database for storage in the internal memory and subsequent use. As a consequence, processing is duly recorded in the database.

EXAMPLES

The following are prophetic examples using the improved process and system of the present disclosure.

Example 1

A photoionization detector (PID) sensor **145**, for example, an EntryRAE PID from RAE Systems, San Jose, Calif., may be used to monitor levels of volatile organic compounds at a fiberglass coating facility. Based on compositional knowledge of the fiberglass composite material being used onsite, it is known that styrene is a primary hazardous vapor present within the facility. Initial data may be taken from a log (20 minute) of styrene concentrations obtained with the PID prior to actual use of the respirator. In the working environment, spikes in concentration levels may occur, such as spikes above 200 ppm, at different time intervals, (e.g., 9 minute and 13 minute). A NIOSH-defined occupational exposure limit (OEL) (predetermined criteria) for styrene is 20 ppm. At 200 ppm and above (i.e., 10× the OEL) the styrene concentration is above the protection factor for a half-face piece air purifying respirator. The data from the PID may be sent to the database **189** of the computer system **150**. These readings are processed by the condition determining mechanism for determining if the above condition satisfies the predetermined criteria to determine the condition of the PPE article in terms of its servicing or replacement.

Example 2

Initial real time styrene concentration data, are collected using a wireless PID worn on a worker, such as obtained by the PID sensor **145**. This data is documented within the database. Based on the cumulative concentration data gathered over a multi-day period, it is determined that the respirator used by the worker should be disposed of after 24 hr. of use. Such a determination was based on NIOSH regulations governing use of the respirator in a workplace having the collected expected styrene concentrations that are assumed to exist, when the respirator is actually used. Both the worker and the safety person may be notified of the appropriate servicing or change-out schedule. Actual use of the respirator is monitored by the smart tag **130** and the sensor **145**. By continuing to monitor exposure data over time, the condition determining process can determine whether the respirator is complying with the NIOSH regulations. Accordingly, the worker and the safety person may take appropriate measures based on the determination. For example, changes in workflow or in engineering controls could make a more stringent or if necessary change the schedules of use.

Example 3

Real-time styrene concentration data are collected using a wireless PID on worker within a fiberglass coating facility, with the data documented within a central database. In this example, the PID **145** is also coupled with an Ekahau™ RTLS smart tag **130**, which provides location information of the wearer within the working environment using a wireless network. The concentration and location data are sent to a central database where they are linked via their time stamp data. By monitoring the data and locations over a period of weeks, a determination may be made that a worker is exposed to the highest periodic concentration of styrene within a particular coating bay within the working environment. With such information, efforts may be undertaken by appropriate personnel to correct the matter, such as providing additional ventilation at the vicinity of the bay. Additionally, the appropriate personnel are able to make sure that the appropriate PPE with sufficient protection factor is worn only within specific areas of the working environment.

Example 4

The sensors of Examples 1, 2, or 3 are utilized via incorporation on or inside the personal protection equipment of a worker to monitor the actual internal environment surrounding the worker. This data is sent wirelessly to the central database to produce reports (e.g., graphics or tables) indicating the cumulative exposure and protection provided for the worker during certain time periods.

It will be appreciated that numerous and varied other arrangements may be readily devised in accordance with these principles by those skilled in the art without departing from the spirit and scope of the invention as claimed.

It will be appreciated that based on the above description, aspects of the disclosure include methods and systems for determining conditions of articles, such as PPE articles, by determining if they satisfy at least one criterion. Further aspects of the disclosure include methods and systems for determining conditions of articles, as noted above, by updating such predetermined criteria to reflect existing conditions in the working environments. Further aspects of the disclosure include methods and systems utilized for ensuring worker safety, and preventing needless discarding of articles by keeping the predetermined criteria contemporaneously valid. Still further aspects of the disclosure include methods and systems utilized for achieving the foregoing economically and expeditiously. Still further aspects of the disclosure include methods and systems utilized for locating working environments in which monitored concentration levels reach hazardous or potentially hazardous levels.

Although the methods and systems of the present disclosure have been described with reference to specific exemplary embodiments, those of ordinary skill in the art will readily appreciate that changes and modifications may be made thereto without departing from the spirit and scope of the present disclosure.

What is claimed is:

1. A method comprising:

providing a plurality of respiratory protection devices, each respective respiratory protection device of the plurality being configured with a respective smart tag;

providing at least one predetermined criterion that governs use of a particular respiratory protection device in a working environment that is external to the particular respiratory protection device, the at least one predetermined criterion being related to whether the particular respiratory protection device should be serviced, repaired, or treated;

providing at least one sensing device configured to sense data that is related to hazardous contaminant concentration levels of the working environment, hazardous contaminant type in the working environment, hazardous contaminant presence in the working environment, or hazardous contaminant absence in the working environment, or chemical breakthrough in the working environment;

acquiring, from the at least one sensing device, sensed data related to the working environment that is external to the respiratory protection device

retrieving smart tag data from the respective smart tag associated with the particular respiratory protection device, the smart tag data including an identification of the particular respiratory protection device and timestamp information indicating at least one of an entry time or an exit time of the respiratory protection device with respect to the working environment; and

storing the sensed data sensed by the sensing device and the smart tag data acquired from the respective smart tag to a database;

processing the sensed data and the smart tag data stored to the database to determine a real-time assessment of a condition of the particular protection device with respect to the working environment, as indicated by a combination of the sensed data and the smart tag data; and

determining whether the real-time assessment of the condition of the particular respiratory protection device satisfies the predetermined criterion pertaining to whether the particular respiratory protection device should be serviced, repaired, or treated.

2. The method of claim **1**, further comprising attaching the respective smart tag to the particular respiratory protection device.

3. The method of claim **1**, further comprising storing one or more results of processing the sensed data and the smart tag data to the database.

4. The method of claim **1**, further including generating at least one report relating to the condition of the particular respiratory protection device.

5. The method of claim **3**, further including generating at least one report relating to the sensed data and the smart tag data.

6. The method of claim **1**, wherein the sensing device is configured to transmit the sensed data wirelessly, and wherein the smart tag is configured to transmit the smart tag data wirelessly.

7. The method of claim **1**, wherein determining a condition of the particular respiratory protection device comprises determining the particular condition based on a condition determining mechanism in a data processing system.

8. The method of claim **1**, wherein the smart tag data includes location information of the respective smart tag.

9. The method of claim **1**, further comprising communicating decision information based on the determination of whether the real-time assessment of the condition of the particular respiratory protection device satisfies the predetermined criterion.

10. A system comprising:

a plurality of respiratory protection devices, each respective respiratory protection device of the plurality being configured with a respective smart tag;

a data processing system including at least one predetermined criterion that governs use of the particular respiratory protection device in a working environment that is external to the particular respiratory protection device, the at least one predetermined criterion being related to whether the particular respiratory protection device should be serviced, repaired, or treated;

at least one sensing device configured to sense data that is related to hazardous contaminant concentration levels of the working environment, hazardous contaminant type, hazardous contaminant presence in the working environment, or hazardous contaminant absence in the working environment, or chemical breakthrough in the working environment;

an informational retrieval system configured to acquire sensed data from the at least one sensing device in the working environment that is external to the respiratory protection device and to acquire smart tag data from the smart tag associated with the particular respiratory protection device, the smart tag data including an identification of the particular respiratory protection device and timestamp information indicating at least one of an entry time or an exit time of the respiratory protection device with respect to the working environment; and

a database configured to store the sensed data and the smart tag data acquired by the informational retrieval system,

the data processing system including a condition determining mechanism configured to process the smart tag data and the sensed data stored to the database to

determine a real-time assessment of a condition of the particular respiratory protection device with respect to the working environment, as indicated by a combination of the sensed data and the smart tag data and to determine whether the real-time assessment of the condition of the particular respiratory protection device satisfies the predetermined criterion pertaining to whether the particular respiratory protection device should be serviced, repaired, or treated.

11. The system of claim **10**, wherein the respective smart tag is coupled to the particular respiratory protection device.

12. The system of claim **10**, wherein the database is further store one or more results of the processing of the sensed data and the smart tag data.

13. The system of claim **10**, further comprising a report mechanism configured to generate at least one report relating to the determination of whether the real-time assessment satisfies the predetermined criterion.

14. The system of claim **13**, wherein the report mechanism is further configured to generate at least one report relating to at least one of the sensed data or the smart tag data stored to the database.

15. The system of claim **10**, wherein the sensing device is configured to transmit the sensed data wirelessly, and wherein the smart tag is configured to transmit the smart tag data wirelessly.

16. The system of claim **10**, wherein the smart tag data includes location information of the respective smart tag.

17. The system of claim **10**, further comprising a communication unit configured to communicate decision information based on the determination of whether the real-time assessment of the condition of the particular respiratory protection device satisfies the predetermined criterion.

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